# Necessity of new paradigm for conquest the millennium / compound class disaster

AUTHOR(S):

MIYAGI, Toyohiko

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## Necessity of new paradigm for conquest the millennium / compound class disaster

***Toyohiko MIYAGI (Tohoku-Gakuin University, Sendai, Japan)***

Immediately after the earthquake, I prepared myself for the tsunami. My intention was to quickly return home.

Boarding a flight from the university, I headed for my town, Shichigahama. From the top of a bridge over the Nanakita River, I saw the tsunami violently flowing up stream. After some couple of seconds, less powerful part of the main tsunami hit the Sendai port. In confusion of honking car horns which was later affected by the surging flood, I abandoned my own car and assisted several others to escape from theirs. With a view to avoid the tsunami water, I made my way to my town on foot.

In company staff of voluntary emergency organizations, I worked to implement disaster measures, but the safety of people weighed heavily on my mind. However, with sea water almost getting past my waist, it was becoming dark. Halfway home, I decided to rest in a three-storey building which had already sheltered up to 17 persons, ranging from children to adults, had gathered there shivering from cold and fear, crowding together to keep warm. We shared any food we have among ourselves and fought off the cold. That day was a very cold day with a little snowfall. Huddled together, throughout the dark and silent night, we waited for the day to break. At five in the morning with sight of the first light, I continued my journey home.

The fire department and other emergency units have been tasked to work all night so as to get acquainted with 'disaster prone areas' and ascertain the degree of damages to the affected areas. My family and home were safe. To my amazement, I discovered that my surrounding neighborhood, especially those living along the ocean had been completely destroyed. I was seized by dread, unable to move myself into the neighborhoods that I once associate with. In company of staff of Japanese Self-defense Force involved in rescue efforts, I soon began to survey the damage. In a very serious situation with information or cue, I thought aloud "What can I do?" I did not count myself a disaster victim. With my wife and son, I started to investigate the relationship between the impact and damage, the height of the tsunami and the depth of the inundated water. I was walking through Matsugahama area when I came across a well-known tsunami scientist. He requested "Please show me the town," This spurred me on. I met with my friends at the emergency headquarters of the town office. While I was traveling in a fire truck headed to the neighborhood of Hanabushi hama area, I encountered a friend with the voluntary emergency organization. The instant our eyes met he shouted out "Sensei (teacher)!" and I shouted out "Mr. Kamata!" I heard a voice say "Hanabushi hama is save!"

Now, I am reexamining disaster preparation. The first reason that I survived is simply "luck."

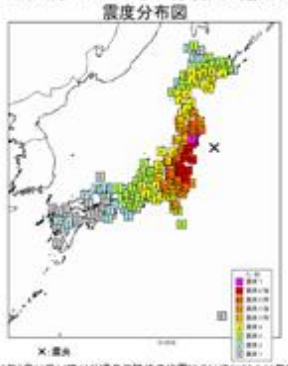
Beyond that I think there was my understanding of the time it takes for a tsunami to arrive, my confirmation of the wave moving up stream, an understanding of terrain, leather gloves, and the desire to get home alive.

Lastly, a thorough knowledge of the local area was seemingly of decisive importance.

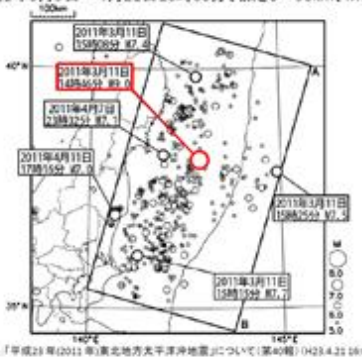
# Out line of the East Japan Great Earthquake 3.11, 2012

○地震の概要（気象庁）
1. 発生日時 平成23年3月11日（金）14時46分頃
2. 震源及び規模（推定）
モーメントマグニチュード Mw9. 0、深さ約　24km
三陸沖（牡鹿半島の東南東130km付近（北緯38. 1度、東経142. 9度））
3. 余震：M7. 0以上 5回、M6. 0以上 73回、M5以上 425回

平成23年3月11日14時46分頃の三陸沖の地震
震度分布図

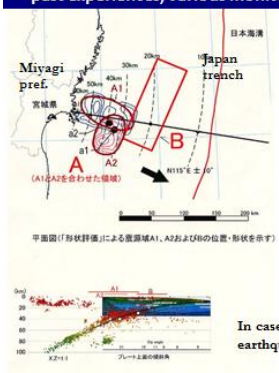


震央分布図
（2011年3月9日～4月21日16時00分、深さ0～90km、M≧5.0）



3

We were **forecasted** the coming large earthquake based on the past experiences, various monitoring and early warning systems.



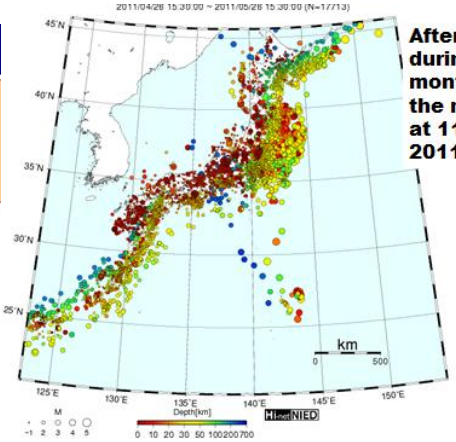



• Last earthquake at the target area:
1978061 2: M.7.4
Human loss:28, Injued:9300
Severe destruction of houses:4200
Partial destruction of houses:74000
Data: Sendai City

The series of earthquake repeated in 25 to 40 years.
Last one occurred in 1978, the next earthquake must come in the neare future.
The probability of the next event is 70% in coming 10 years, 99% in coming 30 years.

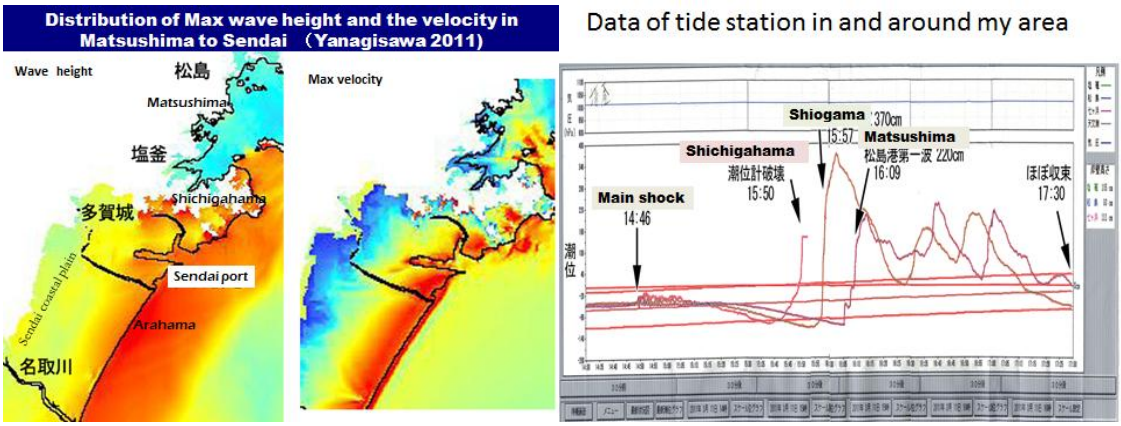
Governmental forecasting at 1st of Jan. 2010

In case of combine A and B will establish M.8 earthquake and severe tsunami.




**After shocks during one month after the main event at 11th March, 2011.**


Tsunami disasters around my house, Shichigahama, Miyagi、Japan




## Formation of the Miyagi coastal forest, and the tsunami disaster

The coastal forest which makes the boundary of the coastal plain in Japan and the sea is a typical artificial strand landscape. if it sees in physiographic and vegetation science, it will be positioned as a "place" which the dynamics of the land and natural system in the land-and-sea boundary region where land is just formed in the front line of the coastal plain formation in Holocene. The vegetation is materialized at there. Even if it is an artificial plantation, as a base element which constitutes the nature of this place, the primary production persons of forest resources, a scene, and an ecosystem and many birds live, and a corridor. The business which makes an artificial coastal forestation was begun and hundreds of years have already passed.

Considering the purpose and function of coastal forest development, he can understand that work of people's hand is also included in the mechanism which cherishes the nature of land-and-sea boundary.

A large coastal plain continues, agricultural work area is formed, and the coast applied to Fukushima Prefecture from Ishinomaki in Miyagi Prefecture is said for the coastal forest to have protected the farmland and human settlements. Although severe destruction arose in the wide range coastal forest in the Great East Japan Earthquake of 3.11, if it observes minutely, some features can be grasped to the way of breaking, and the forests which remained is also seen not a little. It wants for a coastal forest to be made by what kind of land, to look back upon what kind of land nature has been cherished, and to find out the context between the fact and this hazard primarily, here.

Teizan canal and the pine trees

Landscape of Matsushima Tsunami damage of pine tree

**1. Physiographic Background**

1) In a humid temperate climate and tectonic region like Japan, it is important to consider the following: sea-level fluctuation, sediment supply from land, and deposition of sand in a shallow sea, as an action which makes a plain on the seashore.

2) The action which makes sands, such as a littoral current, in a coast shallow sea region, and off shore is also considered as a process of the coastal line.

3) The coastal plain around Sendai is the new land formed 6000 years before. Furthermore, the present seashore and the back marsh were formed about 700 years before.

**2. History of Coastal Forest**

The history of the coastal forest development in this area is long. The coastal forest development enterprise started during the Masamune dynasty of Edo era. The protection of forest against storm surge along Teizan canal is called inheritance of the Masamune Date public with history of over 400 years. Forest Law of Japan was established about 100 years ago, and specification of the forest reserve was performed. Development of the coastal forest was continuing also at the time of this tsunami attack.

**3. Coastal Pine Forest: A typical Forest Structure and Land and Natural System in Japan**

It is developed by the complicated slightly young environment, seeing a coastal forest geologically.

Artificial treatments were added to the land to which the initial condition was set by beach ridges and formation of the back marsh. Then, change of a land natural system was started. (1) The drainage system and de-salt by excavation of Teizan canal. (2) Banking of both banks by excavation of Teizan canal. (3) Reduction of sand dust accompanying attenuation of the wind velocity by forestation, and deposition into a forest. (4) Creation of the ecosystem by forestation, etc. This change became the foundation of new reclamation of a rice field, and built the “original scenery of Japan” called “white sand and green pine forest”. The secondary ecosystem as an autonomous forest structure progressed also inside the forest.

The young pine grove for about 10 to 20 years by the side of the sea side covers the top part of recent beach ridge. Mature pine narrow forest developed at the bank of Tenzan canal as the hundreds years forests. The land side is a back swamp environment. However, large-scale mature forest was also developed also there. The afforested pine can do a root deep originally. Therefore, it seems that the afforestation to the shallower place of the groundwater was quite serious.

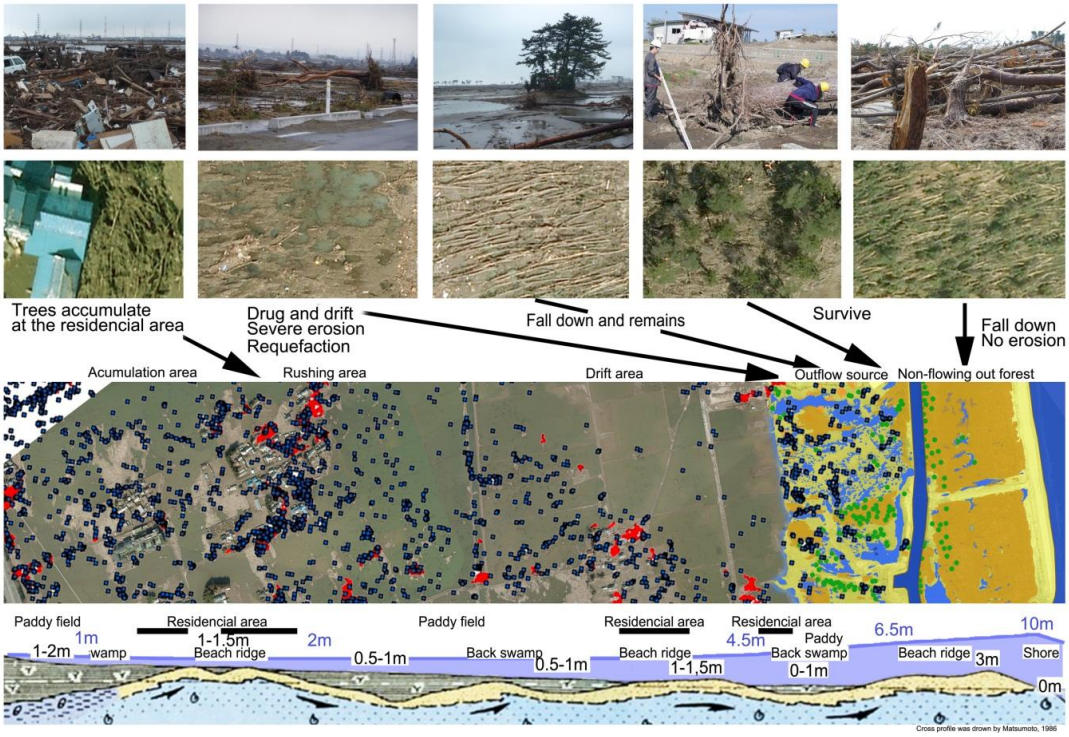
Historically, the tsunami in 1616 took out the drowned person who attacks the seashore of a non vegetation state and amounts to 1800 persons in Sendai.

Activities of the nature and the human for hundreds of years made the motion of dynamic land and the sea quiet, and it created the unit of the land and nature system of a coastal forest region in the land-sea interaction system further.

## 4. Disaster Situation of Coastal Forest in East Japan Great Earthquake

Destruction of a coastal forest is extensive and severe. However, if it sees in detail, it may be complicated, and destruction may hardly have arisen partially. When it looked at the coastal forest from empty, the wonderful spectacle was in sight. Most of driftings are not produced although the pine wood from the top part of beach ridge located in the sea side to Teizan canal is beaten exhaustively. The big tree at the fine high ground of Teizan canal both banks also remains to some extent.

From Teizan canal, although the pine wood by the side of inland is also the mature forest, it survived, and it bent, it broke and collapse, and drifted and intense various destruction have produced it. The countless holes were formed in this area. Furthermore, a huge number of drift trees were left behind in the plain part by the side of land. Although this drift tree destroyed houses, where was it brought about how from where?



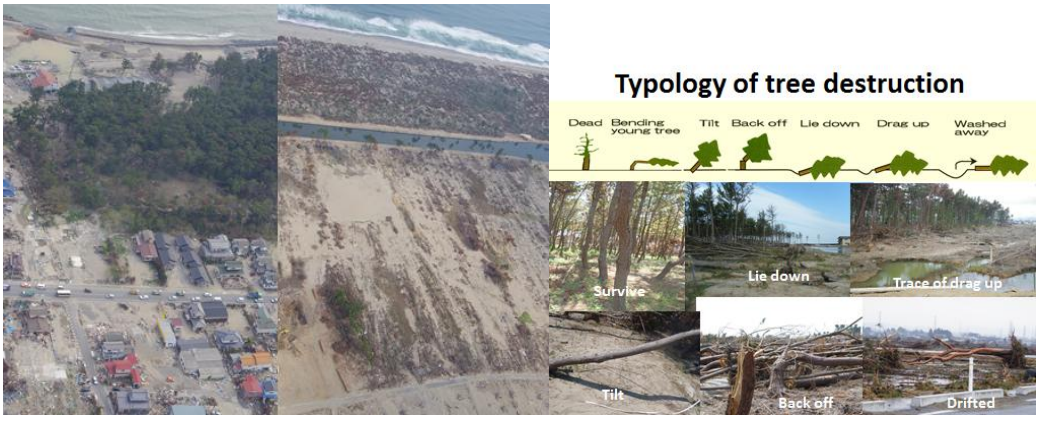

Landform, ground level, tsunami depth, the types of forest destruction and typical photos in case of Arahama area, eastern Sendai coastal plain.

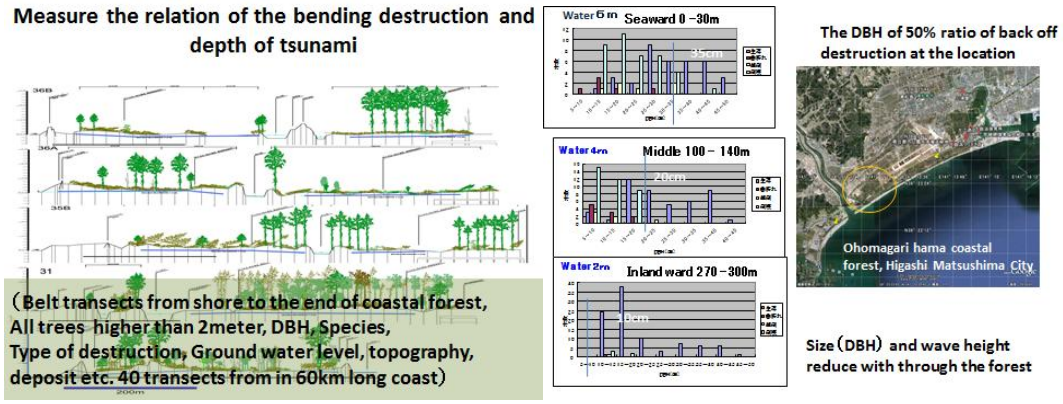
## 5. Suitability of Ground Condition, Coastal Forest, and Tsunami Destruction

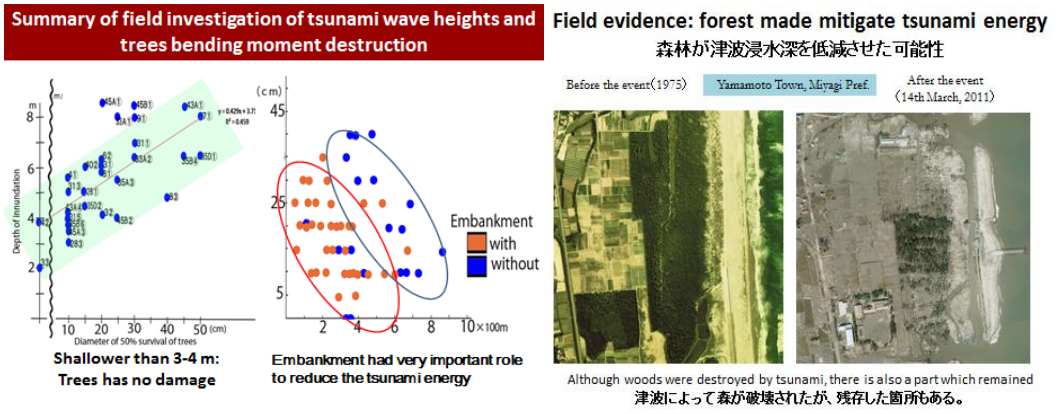
It is thought that the diameter of trees is so thin that the flow velocity and depth of water are large when it assumes that destruction of trees arises according to the fluid power of tsunami that such big destruction occurs. Therefore, if both relations can be quantified, the relation between tsunami power and trees destruction will become clear. When the attack wave quantity of tsunami and the depth of inundation which were measured in various parts of a coast and the forest, and trees bent and writers found the relation of destruction, the place in which it bends and crease destruction excels was a little higher of the foundation quantity which the ground dried mostly.

If tsunami and trees bend and the relation between collapse destruction is found for the depth of inundation and a diameter, in 3 m or less of the depth of inundation, destruction will hardly produce trees 10 cm or less in diameter, either. At the place which intense tsunami which destruction begins to actualize from about the depth of inundation 4m, and exceeds 8 m invaded, a diameter exceeds 40 cm that survival ratio exceeds 50%.

Now, in this great earthquake, the severe earthquake which registers a magnitude of 6 on the Japanese scale 1 hour before tsunami comes for 3 minutes, and has also produced crustal subsidence of the large-scale foundation then. When the earthquake disaster had arisen, didn't change connect also destruction of a forest or between a ground condition and trees arise? Why is the direction of large trees by the inland side of back swamp in the thing with larger destruction than the young tree on beach ridge? Before tsunami invades, a possibility that the situation of reducing the tight-binding power of a root had occurred can be considered. That is, had not phenomena, such as mobilization of soil and liquefaction, arisen by the rise of the groundwater level and strong shock by sedimentation of the foundation? Wasn't the underdeveloped pine of straight roots shaken and changed into the state of driftwoods easily from tsunami, among about 1 hour from the occurrence of an earthquake to the attack of tsunami? Weren't trees drawn out completely by the power of tsunami and doesn't having been generated by the drift tree have the main factors in the instability and the root by foundation degradation in case of an earthquake having been shallow?







Isn't it realistic as for destruction of a coastal forest to think that there were 1; foundation and groundwater conditions, destruction related to a shock, and 2; related the fluid power of the tsunami and the destruction related to the intensity of trees?

## 6. Role Which Coastal Forest Played in Attenuation of Tsunami

If the depth of inundation (the coast front line attack wave quantity) of the tsunami which rolled in to the coastal forest, and trees bend and you understand the relation of crease destruction spatially, it bends from the sea side to the land side, and the diameter (it is a threshold value about 50% of the

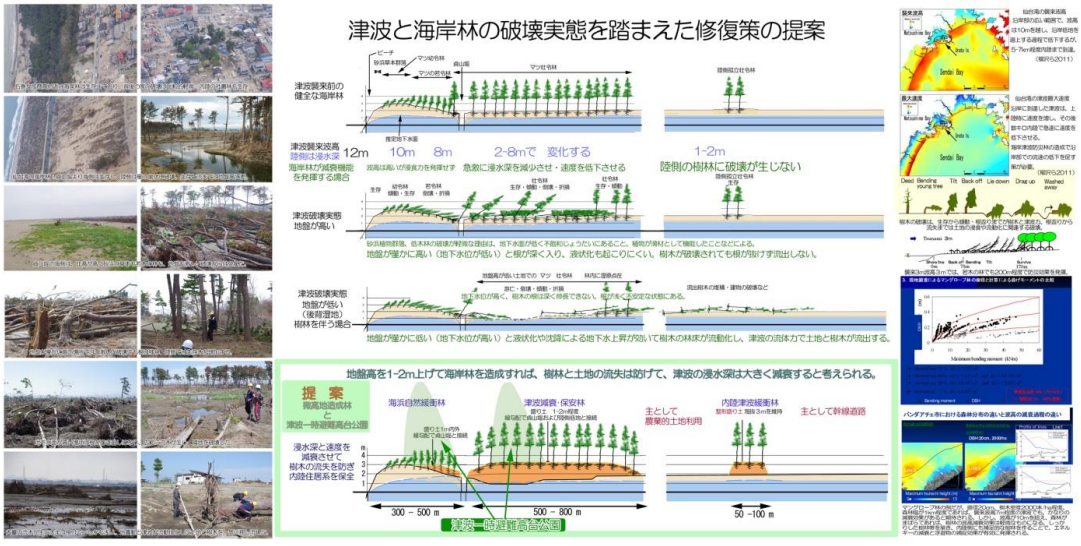
probability of survival) of a crease and survival will decrease favorably, and the depth of inundation will also fall. Such reduction of the depth of inundation is more rapid than the case of a flatland without a forest. Tsunami invades, and signs that the depth of inundation was also reduced can be guessed, reducing the flow velocity in the process in which it passes through the inside of a wood.

If especially it has a lignosa and the shape of roadside trees when trees are not destroyed from tsunami, the effect supplementary to flotsam will be demonstrated. On the other hand, it is observable though the example by which trees are destroyed with a container or rubble is also natural, the depth of inundation was about 2-4m. Couldn't destruction of the house be reduced when the disaster prevention wood was installed in this area?

## 7. Conclusion

In the Sendai coastal plains, human work, such as establishment of Teizan canal and afforestation of a pine trees, worked by the fine geographical feature environment of coastal beach ridges and the back marsh, and a rich scene and ecosystem were built by it. In detail, the afforestation to a ground condition and the place not suiting would also be performed. A present earthquake and tsunami will bring various destructions to such complicated land and vegetation. It seems that the hint about construction of a coastal forest strong against tsunami is also contained from various kinds of destruction. Probably, one of them is the relation between foundation quantity (groundwater level) and tree destruction. The groundwater level is considered to result in change to the style of destruction, and can reduce generating of a drift tree greatly by raising a little foundation at a low place. It cannot be overemphasized that padding of foundation quantity links with attenuation of tsunami directly. It seems that trees will bend and crease destruction will hardly be produced due to the fluid power of tsunami, and trees destruction if the depth of inundation is 4 m or less. Can the foundation quantity and afforestation measure based on tsunami attack prediction be created in the near future based on the knowledge acquired from this occasion?

Although the device of the natural power over hundreds of years and a human activity have been completed the land and nature system of the beautiful complicated coastal forest, in this severe destruction, the device to the construction of a coastal forest which corresponds to destruction like tsunami flexibly and realizes disaster reduction will be called for.




Idea of coastal forest rehabilitation and the model of tsunami destructions

## Landslides on artificial slopes in Sendai

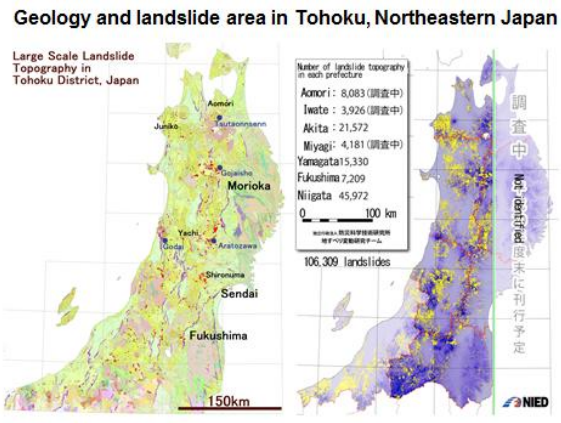
Sendai is a central city and lies close to the epicenter of the Tohoku Earthquake. Sendai and its surrounding area also lead Japan in the scale of the artificial alteration of landform features. Beginning with the construction of an urbanized area of 10 km in 1960s, 70% of the steep slopes of hills were flattered by 1990 to use as residential estates. Such land alteration is now still spreading outward in a circle. Although the residential estate was made artificially flat, it was by cutting and filling; and the boundary between these is quite intricate.

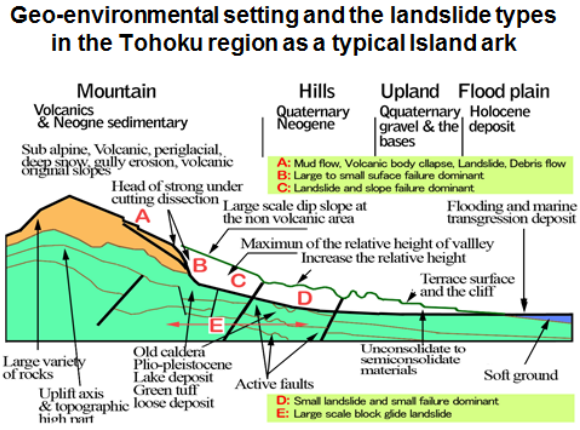
In this earthquake, many landslides were small in size. A considerable number of them occurred in places where artificial landfills were cut and fill boundaries occurred on the artificial land. In Sendai city alone, there are more than 4000 landslides and hazardous slopes, and few hundred residents have been told to evacuate from the homes, the total number of the disastrous small landslides has not been clarified yet.

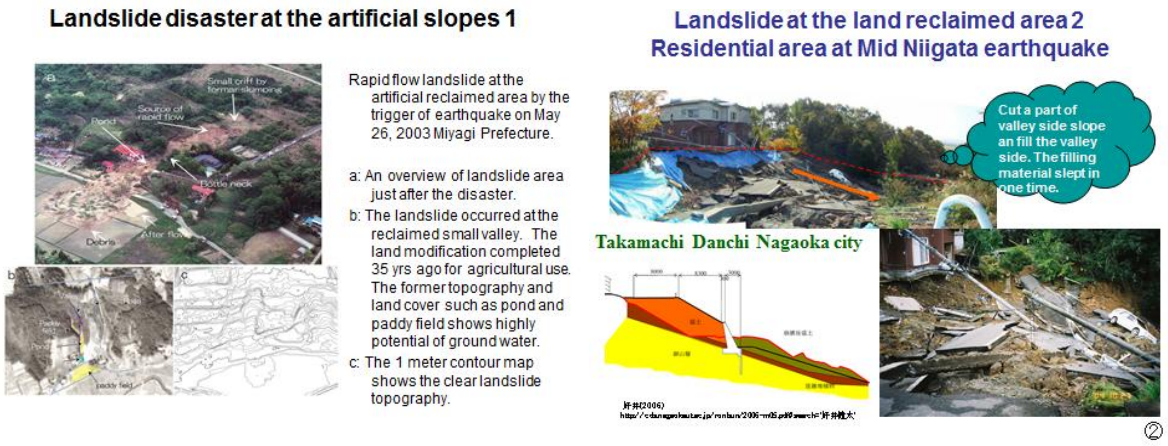
The Japanese Landslide Society has been carrying out projects to evaluate the strength of landfill areas of artificial ground in the Sendai area. The project includes: (1) building a database of the cut and landfill conditions about 50 residential areas in Sendai, (2) determining and classifying the material properties of the landfill materials, (3) establishing a geological model of the landfill areas based on a 5-m grid of columns, and (4) using the three-dimensional stability analysis to calculate the factor of safety of each column by the RBSM method. Using these methods, a distribution map of the landslide potential of the landfill areas was produced. The first test of the model was carried out using landslides in the Takamachi residential area that occurred during the Mid Niigata earthquake in 2004 (Hamasaki et al. 2007). There was good agreement between the model and the actual land deformation.

Also in this earthquake, very good correspondence was seen between the areas likely to landfill areas and the landslides generated by the 2011 Tohoku Japan earthquake.

We will visit a typical landslide disaster area named Oritate residential area, west Sendai.



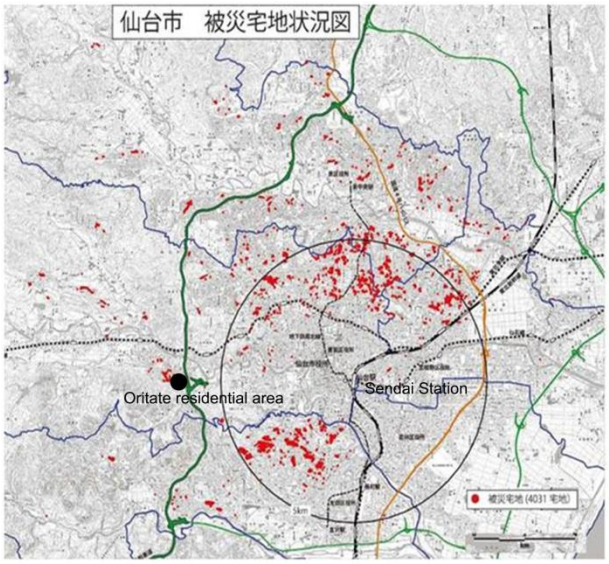





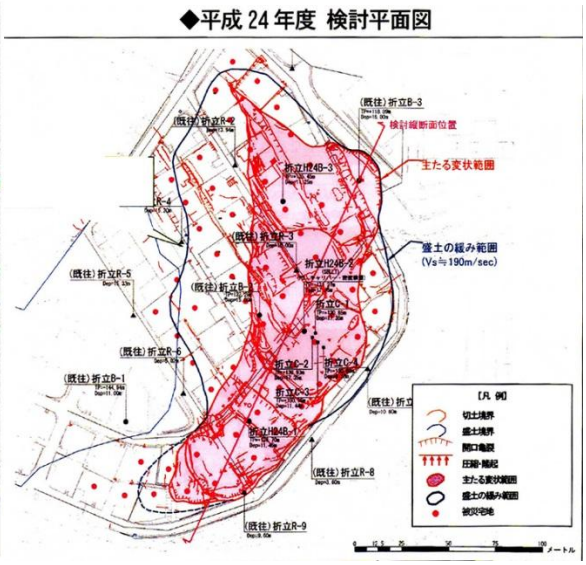

**Landslide at Oritate residential area, west ward of Sendai.**

Landslide hazard of Oritate is one of the typical landslides among the landfilling disasters.

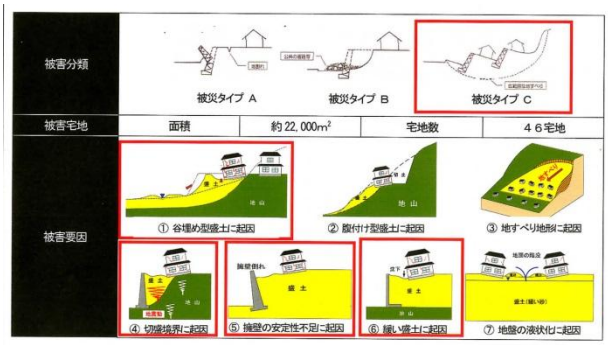
The area was developed in 1969. The area amounts to 40 hectares, and with about 450 houses. The area was typical hilly. Landslides in this area occurred at the moment of the earthquake and gradually moved. The ground water level was very high. The N value of the materials was only 1 to 2. There is large difference between the landfill materials and the original one.




Red spots: Landslides at the residential area.

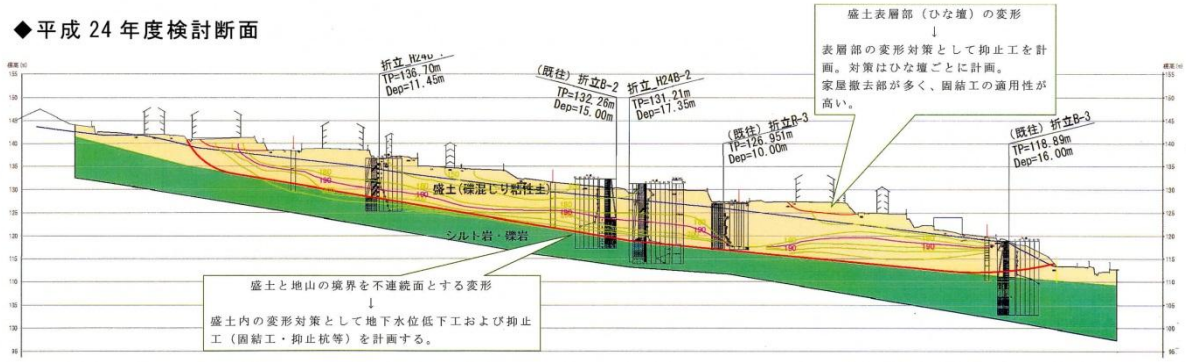



Land displacements at the Oritate area.




Types of modification at Oritate area.

Typical view of the land deformation.




Closs profile of the topographic geologic structure of the landslide at the Oritate area.

*All data of Oritate is referenced from the technical committee of Sendai Residential Area Committee Sendai (2012).*